PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing: 05 July 2001 (05.07.01)	
International application No.: PCT/EP99/10349	Applicant's or agent's file reference: 20990025
International filing date: 23 December 1999 (23.12.99)	Priority date:
Applicant: STEINER, Rolf	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International preliminary Examining Authority on:

05 October 2000 (05.10.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer:

J. Zahra

Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
20990025		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/EP 99/ 10349	23/12/1999	
Applicant		
AGILENT TECHNOLOGIES INC. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 3

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

Line 3: insert "(n=20)" after "plurality"

PATENT COOPERATION TREATY

PTO/PCT Rec'd 10 JAN 2002

From the INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

Barth, Daniel
AGILENT TECHNOLOGIES
DEUTSCHLAND GMBH
Legal Dept., IP Practice Group
Herrenberger Strasse 130
71034 Böblingen
ALLEMAGNE

Legal Europe IP Section
27. Nov. 2001
26.1.02
26.2.02 (not)

PCT

WRITTEN OPINION

(PCT Rule 66)

Date of mailing *(day/month/year)*	26.11.2001
Applicant's or agent's file reference: 20990025	**REPLY DUE** **within 3 month(s)** from the above date of mailing

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP99/10349	23/12/1999	23/12/1999

International Patent Classification (IPC) or both national classification and IPC

G01R29/02

Applicant

AGILENT TECHNOLOGIES INC. et al.

1. This written opinion is the **first** drawn up by this International Preliminary Examining Authority.

2. This opinion contains indications relating to the following items:

I	☒	Basis of the opinion
II	☐	Priority
III	☐	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	☐	Lack of unity of invention
V	☐	Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	☐	Certain document cited
VII	☐	Certain defects in the international application
VIII	☒	Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

Also: For an additional opportunity to submit amendments, see Rule 66.4. For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4 bis. For an informal communication with the examiner, see Rule 66.6.

If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: 23/04/2002.

Name and mailing address of the international preliminary examining authority:
European Patent Office
D-80298 Munich
Tel. +49 89 2399 - 0 Tx: 523656 epmu d
Fax: +49 89 2399 - 4465

Authorized officer / Examiner
Santos, P

Formalities officer (incl. extension of time limits)
Baumann, H
Telephone No. +49 89 2399 2131

I. Basis of the opinion

1. With regard to the **elements** of the international application (Replacement *sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed"*):

Description, pages:

1-9 as originally filed

Claims, No.:

1-11 as originally filed

Drawings, sheets:

1/2-2/2 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item VIII

1. The provision of three alternative definitions in the independent method **claims 1, 7 and 8** as well as in the two independent apparatus **claims 10 and 11** may, under the rules pertaining in certains national and regional procedures (e.g. European), be considered to render obscure what are the essential features of the, according to Rule 13(1) PCT, necessarily single invention. A clarity objection may therefore be incurred at that stage.

2. It is clear from the description that the following features are essential to the definition of the invention:

   (1) a window function is applied to the signal series;
   (2) a corrected measured signal is calculated from the windowed signal series using the transfer function of the system.

   Since independent **claim 8** does not contain these features it does not meet the requirement following from Article 6 PCT taken in combination with Rule 6.3(b) PCT that any independent claim must contain all the technical features essential to the definition of the invention.

10/069,084

PATENT COOPERATION TREATY

PCT

REC'D 09 APR 2002
WIPO PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

3

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
20990025		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP99/10349	23/12/1999	23/12/1999
International Patent Classification (IPC) or national classification and IPC G01R29/02		
Applicant AGILENT TECHNOLOGIES INC. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
05/10/2000	05.04.2002
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Santos, P Telephone No. +49 89 2399 8359

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP99/10349

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-9 as originally filed

Claims, No.:

1-11 as originally filed

Drawings, sheets:

1/2-2/2 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-11
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-11
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-11
	No:	Claims	

2. Citations and explanations
see separate sheet

1. Reference is made to the following documents:

D1: US-A-5 305 242 (KIKUCHI NORIYOSHI ET AL) 19 April 1994 (1994-04-19)
D2: PATENT ABSTRACTS OF JAPAN vol. 016, no. 323 (P-1386), 15 July 1992 (1992-07-15) -& JP 04 095879 A (NISSHIN STEEL CO LTD), 27 March 1992 (1992-03-27)

2. The present invention relates to a method and apparatus for measuring and digitally correcting a signal transmitted through a communications channel and consequently subject to distortion resulting from the limited bandwidth of the channel. For that purpose, the spectrum of the sampled measured signal is multiplied by the inverse of the transfer function of the channel after its temporal sequence is multiplied by a spectral window.

3. The present invention aims at reducing the effects of spectral leakage resulting from the windowing process, in particular when the signal to be measured is a non-periodic single pulse, by sampling the measured signal and transforming it into a periodic signal series before processing it by the window function.

4. The documents D1 and D2 disclose systems and methods to reduce the distortion of measured sampled periodic signals, wherein the window function is synchronised with the zero-crossing instants of the measured waveform, thereby reducing spectral leakage.

   The present invention, as defined in independent claims 1, 7, 8, 9, 10 and 11, distinguishes itself from these known disclosures in that a signal series is provided as a plurality of the sampled signal sequences, resulting from sampling the measured signal, put together successively.

   Since none of the cited documents discloses or hints at this feature, independent claims 1, 7, 8, 9, 10 and 11 appear to meet the requirements of Art. 33 PCT.

5. Claims 2-6 are dependent on claim 1 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

6. The provision of three alternative definitions of the invention in the form of independent method claims 1, 7 and 8 as well as in the two independent apparatus claims 10 and 11 may, under the rules pertaining in certains national and regional procedures (e.g. European), be considered to render obscure what are the essential features of the, according to Rule 13(1) PCT, necessarily single invention. A clarity objection may therefore be incurred at that stage.

7. It is clear from the description that the following features are essential to the definition of the invention:

(1) a window function is applied to the signal series;
(2) a corrected measured signal is calculated from the windowed signal series using the transfer function of the system.

Since independent claim 8 does not contain these features it does not meet the requirement following from Article 6 PCT taken in combination with Rule 6.3(b) PCT that any independent claim must contain all the technical features essential to the definition of the invention.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 July 2001 (05.07.2001)

PCT

(10) International Publication Number
WO 01/48492 A1

(51) International Patent Classification[7]: G01R 29/02

(21) International Application Number: PCT/EP99/10349

(22) International Filing Date:
23 December 1999 (23.12.1999)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: AGILENT TECHNOLOGIES INC. a Delaware corporation [US/US]; 395 Page Mill Road, Palo Alto, CA 94303-0870, -- (US).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: STEINER, Rolf [DE/DE]; Taläcker 38, D-72108 Rottenburg (DE).

(74) Agent: BARTH, Daniel; Agilent Technologies Deutschland GmbH, Legal Department, IP Practice Group, Herrenberger Strasse 130, D-71034 Böblingen (DE).

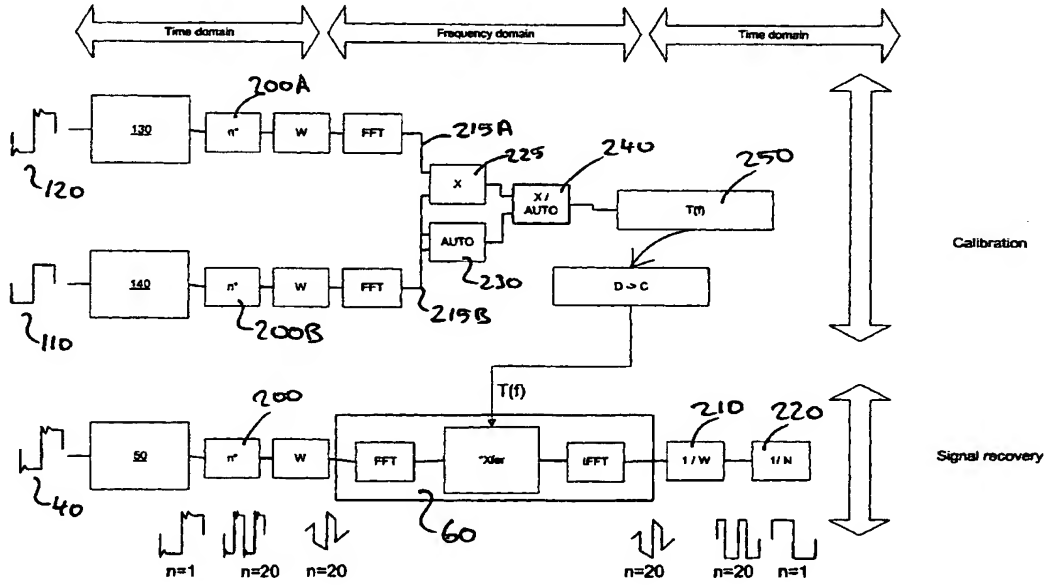
(81) Designated States *(national)*: JP, US.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: MINIMIZING WINDOWING EFFECTS IN PARTICULAR FOR SIGNAL RECOVERY



(57) Abstract: Disclosed is the correcting of a measured signal (40), such as a high-speed digital pulse, transmitted through a system (30). The measured signal (40) is sampled to a sampled signal sequence, and a signal series is provided as a plurality (n=20) of the sampled signal sequences put together successively. The signal series is windowed with a window function, and a corrected measured signal is recalculated from the windowed signal series using information about the frequency-dependency of the system.

WO 01/48492 A1

MINIMIZING WINDOWING EFFECTS IN PARTICULAR FOR SIGNAL RECOVERY

BACKGROUND OF THE INVENTION

The present invention relates to correcting a measured signal transmitted through a system.

Effective and accurate measuring of high-speed pulses requires careful design of the measuring setups and methods. Increased measurement accuracy of signals with increasing frequencies together with a high degree of automatization is getting more and more difficult to achieve. While reaching ranges of above 1 GHz, signal distortion resulting from each connection, cables, switches or other elements in the transmission path is influencing the pulse performances significantly, for example with respect to pulse rise and/or fall time, ringing, droop, overshoot, or the like. Such kind of distortion is generally tried to be minimized by using (usually more expensive) high-speed cables, high-frequency connectors, switches, etc. and/or by optimizing the measurement set-up to minimize signal connection lengths. Moreover, a certain trade off between measurement accuracy and the degree of measurement automatization is often required.

Another approach for improving measuring signals can be accomplished by determining the distortion of the signal transmission path and recalculating an ideal signal (i.e. without being distorted by the signal transmission path) from the actually measured signal. The techniques for recalculating the ideal signal are well established in the theory of communications. The response of a linear system to a signal can be determined in the time domain by using the principle of convolution, and in the frequency domain by applying the principle of superposition to responses produced by the individual frequency components applied for the frequency domain representation. Multiplication in the frequency domain is equivalent to convolution in the time domain, and vice versa. A detailed break down of the theory, both for time domain and frequency domain analysis, can be readily

CONFIRMATION COPY

taken e.g. from the introductory chapter "Signals and Channels" in "Telecommunications engineering", ISBN 0-412-38190-7, by J. Dunlop.

For the sake of simplicity and since signal recalculations are mainly applied in the frequency domain, the principle of signal recalculation shall be explained in the following mainly with respect to frequency domain analysis. It is clear, however, that signal recalculations in the time domain applying convolution techniques can be applied accordingly.

Fig. 1 illustrates the principle of signal recalculation in the frequency domain. An input signal 10 provided from a signal source 20 is transmitted through a communication channel generally represented herein as a system 30. In general, the system 30 modifies or distorts the waveform of the input signal 10 transmitted through the system 30 to an output signal 40. The amount of distortion produced by the system 30 is thereby determined by the transfer function (i.e. attenuation and phase shift as a function of frequency) of the system 30. The determination of the transfer function will be explained in more detail with respect to Fig. 2. The output signal 40 is measured by a measuring device 50 such as an oscilloscope.

Before recalculating the input signal 10 from the output signal 40 by a recalculation unit 60, a window function W is usually applied to the measured output signal 40 for reducing spectral leakage effects. Typical window functions are Hanning–Window, Blackman Window, or Hamming Window. The recalculation unit 60 then transforms the windowed signal from the time domain into the frequency domain usually by applying a Fast Fourier Transformation (FFT). The transformed signal is then divided by the transfer function T(f) of the system 30, and the result thereof is retransformed from the frequency domain back into the time domain usually by applying an Inverse Fast Fourier Transformation (IFFT). The result of the retransformation represents a recalculated signal 70, which substantially corresponds to the input signal 10. The recalculated signal 70 might be applied to a signal source 80 for generating a physical signal 90 from the recalculated signal 70 or could be applied for analyzing the recalculated signal 70 with respect to its

characteristics and properties.

It is clear that the recalculated signal 70 ideally equals the input signal 10 in case that:

- the transfer function T(f) applied in the recalculation unit 60 fully equals the transfer function of the system 30,
- the transformation and retransformation steps are completely inverse,
- the measuring device 50 and the recalculation unit 60 have no transfer function(s) further modulating the signals, and
- the window function W has no influence on the signals.

It is clear that any deviation from the ideal situation as outlined above will adversely affect the signal recalculation process and lead to deviations of the recalculated signal 70 from the input signal 10.

Fig. 2 illustrates the principle for determining a transfer function. A reference signal generator 100 applies a reference signal 110 to the system 30 for which the transfer function T(f) is to be determined. The reference signal 110 transmitted through the system 30 is distorted to a signal response 120 measured by a first measuring device 130. The measured signal response 120 is modulated by a window function (block W) and transformed into the frequency domain (block FFT) as a function O(f). Accordingly, the reference signal 110 is measured by a second measuring device 140, modulated by a window function (block W) and transformed into the frequency domain (block FFT) as a function I(f). The transfer function T(f) of the system 30 is then determined in a calculation unit 150 by dividing the frequency-transformed signal response O(f) by the frequency-transformed reference signal I(f).

It is clear that - dependent on the characteristics of the respective signals - the window functions W applied in Figs. 1 and 2 can either be the same or different

window functions.

Another way for determining the transfer function T(f) would be to measure the response of the system 30 to an applied Dirac pulse.

As noted above, the frequency domain analysis executed by the recalculation unit 60 in Fig. 1 can also be undertaken in the time domain, since the time domain and the frequency domain are linked by the Fourier transform. In that case, the recalculation unit 60 would provide a convolution analysis, however, leading correspondingly to the recalculated signal 70.

When performing the recalculation as outlined for Fig. 1, several difficulties have to encountered:

- Firstly, sampling oscilloscopes are generally applied as standard measurement instruments for characterizing (digital) signals, e.g. for determining overshoot or ringing of a digital pulse. For achieving highest accuracy on signal performance measurements, it is necessary to set the time base of the oscilloscope to a value that shows only a few signal periods or even less than one signal period on the screen. This allows maximizing the sampling density of the measured signal. On the other hand, for performing the frequency transformation (such as FFT) a significant number of periods of the measured signal should be used for minimizing the effect of the signal windowing on the measurement accuracy.

  High sampling resolution and to put a huge number of signal periods into one screen shot for minimizing windowing effects, however, are contravening requirements, and a certain trade off between those requirements has to be made. However, it is apparent that any limitation of the sampling accuracy in the measuring process of Fig. 1 will correspondingly lead to a reduced accuracy of the recalculated signal 70 with respect to the input signal 10. Accordingly, any inaccuracy in the sampling process of Fig. 2 (by the measuring devices 130 and 140) will lead to a reduced accuracy of the transfer function T(f), which again

reduces the accuracy of the recalculation process in the recalculation unit 60 of Fig. 1.

- Secondly, the transfer function T(f) can only be determined for discrete frequencies and a limited frequency range. That means, that if the time base of the measuring device 50 has to be changed, the transfer function should be determined again. That requires a huge effort for characterizing each measurement path for all different time bases used.

- Thirdly, even with highest accuracy for the sampling process and determination of the transfer function, the recalculated signal 70 is still slightly distorted under the influence of the windowing function.

- Fourthly, the determination of the transfer function is strongly dependent on the quality of the reference source 100 providing the reference signal 110. Any frequency limitation of the reference source 110 will automatically reduce the accuracy of the determined transfer function.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an improved correction of measured signals. The object is solved by the independent claims. Preferred embodiments are shown by the dependent claims.

According to the invention, the signal correction process can be significantly improved in that - before modulating the corrected measured signal with a window function and recalculating the corrected measured signal - the measured signal is sampled, and the sample sequence is reproduced (preferably copied) to a series of several successive sequences. This signal series of a plurality of the sampled signal sequences is then applied for the windowing process. This allows that the measured signal can be sampled with highest accuracy, while windowing effects can be encountered by choosing a sufficiently high number of the sampled signal sequences put together to the signal series.

Since the invention does not depend on the specific method applied for recalculating corrected measured signals, frequency domain analysis as well as time domain analysis can be applied, as described in the introductory part of the description. Preferably, the recalculation process is performed using a frequency domain transformation of the windowed signal series, and by multiplying the transformed signal series with the inverse transfer function of the system. The result is retransformed into the time domain, and the corrected measured signal can be extracted therefrom preferably by selecting one sequence corresponding to the sequence of the measured signal.

In a preferred embodiment, the corrected signal sequence is selected substantially from a middle range of the signal series resulting from the recalculation process of the windowed signal series.

In another preferred embodiment, a demodulation process inverse to the modulation of the signal series with the window function is applied to the results of the recalculation process of the windowed signal series. This allows further reducing distortion effects resulting from the windowing process.

It is to be understood that the inventive signal sampling and accumulation is not limited to signal recalculations but can be applied in order to reduce windowing effects in any kind of application.

It is clear that the invention can be partly or entirely embodied by one or more suitable software programs, which can be stored on or otherwise provided by any kind of data carrier, and which might be executed in or by any suitable data processing unit.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and many of the attendant advantages of the present invention will be readily appreciated and become better understood by reference to the following detailed description when considering in connection with the accompanied drawings. Features that are substantially or functionally equal or similar will be

referred to with the same reference sign(s).

Fig. 1 illustrates the principle of signal recalculation in the frequency domain,

Fig. 2 illustrates the principle for determining a transfer function, and

Fig. 3 shows a preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 3 shows a preferred embodiment of the invention, whereby the lower part depicts the signal recovery process for correcting a measured signal, and the upper part illustrates the calibration process for determining the transfer function for the signal recovery process. Fig. 3 substantially corresponds to the measuring principles as depicted for Figs. 1 and 2.

The measuring device 50 in Fig. 3, as explained for Fig. 1, measures and samples the output signal 40 of the system 30. However, in contrast with the explanation as given for Fig. 1, the output signal 40 can be sampled with highest accuracy as provided by the measuring device 50. This allows that sampling distortion can be minimized to a high degree. In case of a periodic output signal, e.g. one period can be sampled with maximum sample density for achieving highest accuracy.

The sampled output signal 40 is then applied to a signal multiplication unit 200, which captures the sampled output signal 40 and appends it thereto (n-1)-times. This results in an n-periodic signal, whereby each period represents the sampled output signal 40. In the example of Fig. 3, the sampled output signal 40 is added (or copied) nineteen times to the "original" sampled output signal 40, thus resulting in a 20-periods signal

The n-period signal provided from the multiplication unit 200 is then modulated with a window function W and supplied to the recalculation unit 60. The recalculation unit 60, as explained for Fig. 1, provides a Fourier transform (block FFT) of the windowed n-period signal, divides (block *Xfer) the frequency transformed signal

by the transfer function T(f) of the system 30, and finally retransforms (block IFFT) the result back into the time domain.

The recalculated n-periodic signal provided from the recalculation unit 60 now contains n-times the recalculated signal 70, which again can be received e.g. by selecting one period.

In a preferred embodiment, the recalculated n-period signal provided from the recalculation unit 60 will be demodulated from the windowing function W in a demodulation unit 210. The demodulation unit 210 preferably divides the n-period signal from the recalculation unit 60 by the windowing function W (as applied in the previous windowing process).

In another embodiment, the n-periodic signal from the recalculation unit 60 is applied either directly or via the demodulation unit 210 to a period selection unit 220. The period selection unit 220 selects one period of the n-periodic signal, preferably in a middle range of the n-periodic signal. In the example of Fig. 3, the period selection unit 220 will select the eleventh period of the 20-period signal.

The upper part of Fig. 3 illustrates the calibration process preferably applied for determining the transfer function T(f) of the system 30. It is clear, however, that the transfer function T(f) can also be determined by other processes as known in the art, and that the invention is not limited to the specific embodiment as depicted in the upper part of Fig. 3. In accordance with the above said for Fig. 2, the first measuring device 130 measures and samples the signal response 120 of the system 30, while the second measuring device 140 measures and samples the reference signal 110 applied to the system 30. Also in accordance with the above said, a multiplication unit 200A provides an n-period signal from the sampled signal response 120, and a multiplication unit 200B provides an n-period signal from the sampled reference signal 110. The signal response 120 as well as the reference signal 110 are preferably sampled with highest accuracy achievable by the measuring units 130 and 140. The n-periods signals from the multiplication units 200A and 200B are each modulated with a window function W and transformed into

the frequency domain, as indicated by the respective blocks W and FFT, to a transformed signal response 210A and a transformed reference signal 210B.

The transfer function T(f) can then be determined by dividing the transformed signal response 210A by the transformed reference signal 210B. However, instead of directly dividing the transformed signal response 210A by the transformed reference signal 210B, a cross spectrum and an auto spectrum can be determined, as shown in the upper part of Fig. 3. A cross spectrum unit 225 determines the cross spectrum by complex multiplying the spectra of the transformed signal response 215A and the transformed reference signal 215B. An auto spectrum unit 230 determines the auto spectrum by complex multiplying the spectrum of the transformed reference signal 210B with itself. A transfer function determining unit 240 can then determine the transfer function T(f) by dividing the determined cross spectrum by the determined auto spectrum. This allows eliminating white noise effects thus increasing accuracy.

The determined transfer function T(f) is then preferably stored in a storage 250 and can be requested from the recalculation unit 60.

In a preferred embodiment, an interpolation unit 260 provides an interpolation of the transfer function T(f) from discrete frequency values to a continued frequency spectrum. This is preferably accomplished by a linear interpolation between two discrete frequency points or a spline interpolation.

CLAIMS:

1. A method for correcting a measured signal, preferably a high-speed digital pulse, transmitted through a system, the method comprising the steps of:

   (a) sampling the measured signal to a sampled signal sequence,

   (b) providing a signal series as a plurality of the sampled signal sequences put together successively,

   (c) windowing the signal series with a window function, and

   (d) recalculating a corrected measured signal from the windowed signal series using information about the frequency-dependency of the system.

2. The method of claim 1, wherein step (d) comprises the steps of:

   (d1) transforming the windowed signal series from time domain into frequency domain,

   (d2) modifying the transformed signal series with a transfer function as a function of frequency of the system, preferably by multiplying the transformed signal series with the inverse transfer function of the system,

   (d3) re-transforming the modified transformed signal series back from the frequency domain into the time domain, and

   (d4) receiving the corrected measured signal from the re-transformed signal series.

3. The method of claim 1 or 2, wherein step (d) further comprises a step of modifying the corrected measured signal with a function inverse to the window function.

4. The method of claim 2 or 3, wherein the step (d4) comprises a step of

selecting a corrected signal sequence substantially corresponding to the sampled signal sequence.

5. The method of claim 4, wherein the selected corrected signal sequence is selected substantially from a middle range of the re-transformed signal series.

6. The method according to any one of the above claims, wherein the sampling in step (a) is executed with high and preferably highest accuracy.

7. A method for correcting a measured signal, preferably a high-speed digital pulse, transmitted through a system having a transfer function as a function of frequency, the method comprising the steps of:

(a) sampling the measured signal to a sampled signal sequence,

(b) providing a signal series as a plurality of the sampled signal sequences put together successively,

(c) windowing the signal series with a window function,

(d) transforming the windowed signal series from time domain into frequency domain,

(e) modifying the transformed signal series with the transfer function of the system, preferably by multiplying the transformed signal series with the inverse transfer function of the system,

(f) re-transforming the modified transformed signal series back from the frequency domain into the time domain, and

(g) receiving a corrected measured signal from the re-transformed signal series.

8. A method for providing a measured signal, preferably a high-speed digital pulse, for further processing, the method comprising the steps of:

(a) sampling the measured signal to a sampled signal sequence, and

(b) providing a signal series as a plurality of the sampled signal sequences put together successively.

9. A software program storable on a data carrier, for executing any one of the above methods when operated in a computer system.

10. An apparatus for executing one of the methods according to any one of the claims 1-9.

11. An apparatus for correcting a measured signal (40), preferably a high-speed digital pulse, transmitted through a system (30), comprising:

means (50)) for sampling the measured signal (40) to a sampled signal sequence,

means (200) for providing a signal series as a plurality of the sampled signal sequences put together successively,

means (W) for windowing the signal series with a window function, and

means (60) for recalculating a corrected measured signal from the windowed signal series using information about the frequency-dependency of the system.

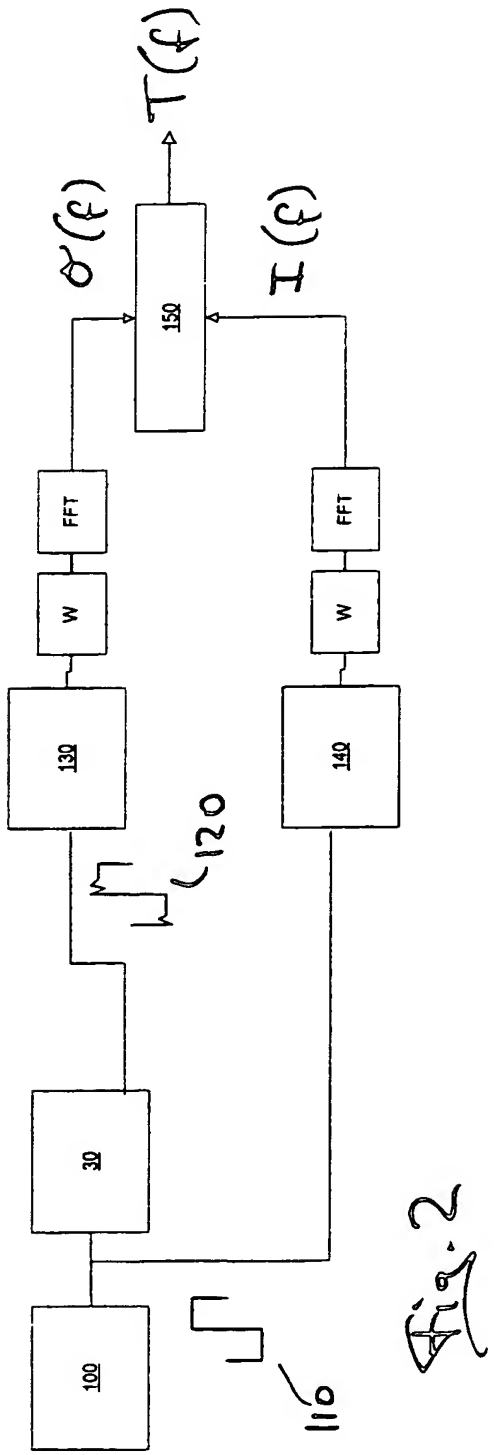

100
30
130
140
FFT
W
FFT
W
150
γ(f)
H(f)
T(f)
110
120

Fig. 2

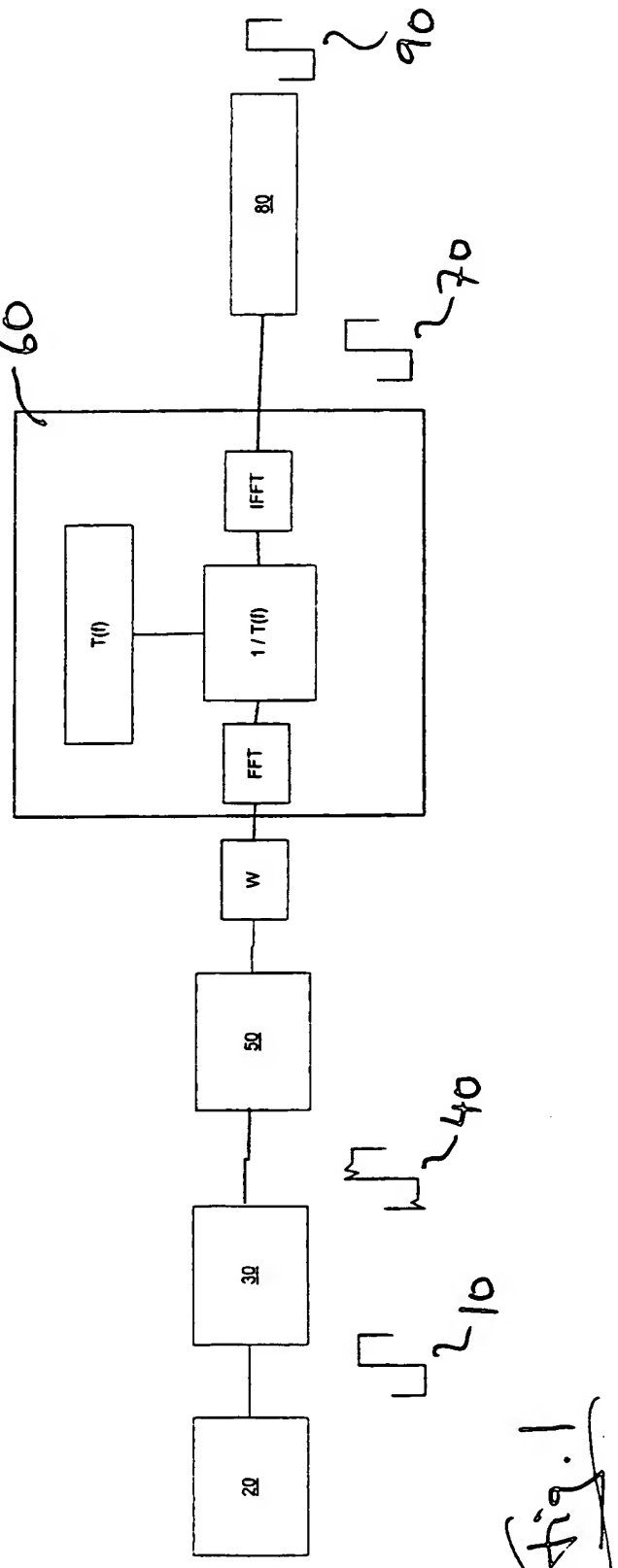

20
30
50
W
FFT
T(f)
1 / T(f)
IFFT
80
90
60
70
10
40

Fig. 1

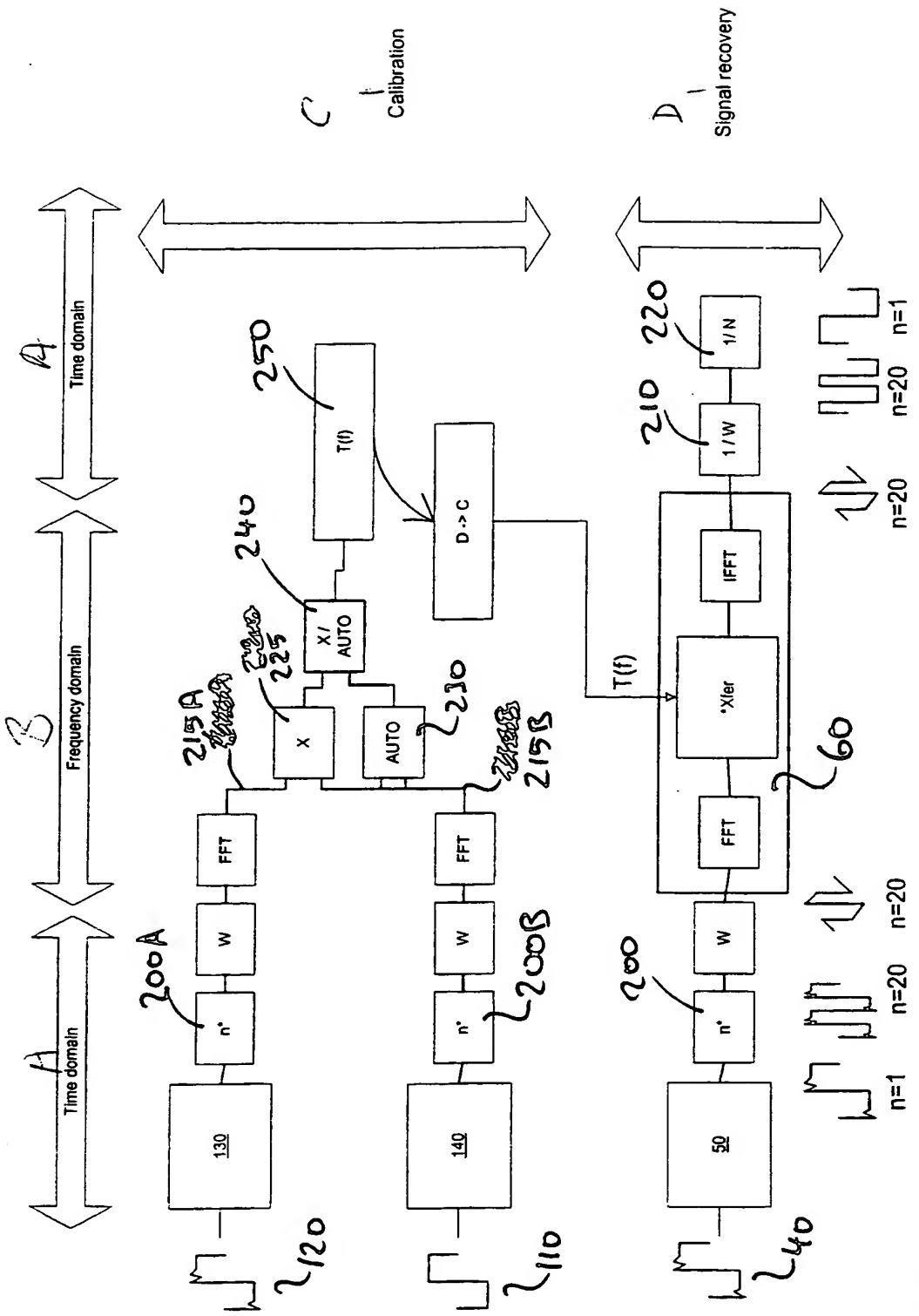

A
Time domain
B
Frequency domain
C
Calibration
D
Signal recovery
T(f)
D -> C
X/ AUTO
X
AUTO
FFT
W
n'
IFFT
1/W
1/N
'Xler
n=1
n=20
130
140
50
120
110
40
200A
200B
200
210
220
230
240
250
60

Fig. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/10349

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R29/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R H03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 702 612 A (FRANCE TELECOM ;TELEDIFFUSION FSE) 16 September 1994 (1994-09-16) abstract; figures 1-4,7,11	1,7-11
A	DE 44 11 098 A (ROHDE & SCHWARZ) 5 October 1995 (1995-10-05) abstract; claim; figure column 1, line 5 - line 38 column 2, line 28 - line 36	1-11
X	US 5 305 242 A (KIKUCHI NORIYOSHI ET AL) 19 April 1994 (1994-04-19) abstract; figures 2A-3B,10 column 1, line 27 - line 47	8-10

-/—

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 August 2000	29/08/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Fritz, S

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	LYONS R: "WINDOWING FUNCTIONS IMPROVE FFT RESULTS" TEST AND MEASUREMENT WORLD. (INC. ELECTRONICS TEST),US,CAHNERS PUBLISHING, DENVER, vol. 18, no. 10, 1 September 1998 (1998-09-01), pages 53-54,56,58,60, XP000779830 ISSN: 0744-1657 page 56, last paragraph; figure 3 page 58	1-11
X	PATENT ABSTRACTS OF JAPAN vol. 016, no. 323 (P-1386), 15 July 1992 (1992-07-15) -& JP 04 095879 A (NISSHIN STEEL CO LTD), 27 March 1992 (1992-03-27) abstract; figures 1-3	8-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern: al Application No
PCT/EP 99/10349

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2702612 A	16-09-1994	DE 69403328 D	26-06-1997
		DE 69403328 T	06-11-1997
		EP 0688476 A	27-12-1995
		WO 9421041 A	15-09-1994
		JP 8507421 T	06-08-1996
		US 5768165 A	16-06-1998
DE 4411098 A	05-10-1995	NONE	
US 5305242 A	19-04-1994	JP 2771420 B	02-07-1998
		JP 6043192 A	18-02-1994
JP 04095879 A	27-03-1992	NONE	

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(81) Designated States *(national)*: JP, US.

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see PCT Gazette No. 34/2002 of 22 August 2002, Section II

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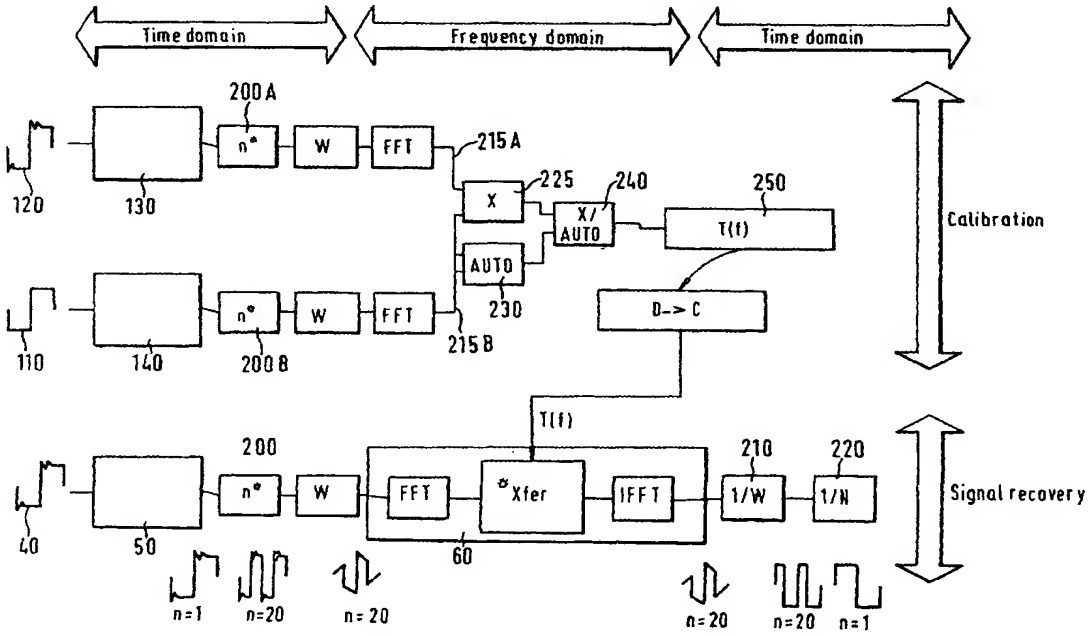
(54) Title: MINIMIZING WINDOWING EFFECTS IN PARTICULAR FOR SIGNAL RECOVERY



(57) Abstract: Disclosed is the correcting of a measured signal (40), such as a high-speed digital pulse, transmitted through a system (30). The measured signal (40) is sampled to a sampled signal sequence, and a signal series is provided as a plurality (n=20) of the sampled signal sequences put together successively. The signal series is windowed with a window function, and a corrected measured signal is recalculated from the windowed signal series using information about the frequency-dependency of the system.

WO 01/048492 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

MINIMIZING WINDOWING EFFECTS IN PARTICULAR FOR SIGNAL RECOVERY

BACKGROUND OF THE INVENTION

The present invention relates to correcting a measured signal transmitted through a system.

Effective and accurate measuring of high-speed pulses requires careful design of the measuring setups and methods. Increased measurement accuracy of signals with increasing frequencies together with a high degree of automatization is getting more and more difficult to achieve. While reaching ranges of above 1 GHz, signal distortion resulting from each connection, cables, switches or other elements in the transmission path is influencing the pulse performances significantly, for example with respect to pulse rise and/or fall time, ringing, droop, overshoot, or the like. Such kind of distortion is generally tried to be minimized by using (usually more expensive) high-speed cables, high-frequency connectors, switches, etc. and/or by optimizing the measurement set-up to minimize signal connection lengths. Moreover, a certain trade off between measurement accuracy and the degree of measurement automatization is often required.

Another approach for improving measuring signals can be accomplished by determining the distortion of the signal transmission path and recalculating an ideal signal (i.e. without being distorted by the signal transmission path) from the actually measured signal. The techniques for recalculating the ideal signal are well established in the theory of communications. The response of a linear system to a signal can be determined in the time domain by using the principle of convolution, and in the frequency domain by applying the principle of superposition to responses produced by the individual frequency components applied for the frequency domain representation. Multiplication in the frequency domain is equivalent to convolution in the time domain, and vice versa. A detailed break down of the theory, both for time domain and frequency domain analysis, can be readily

CONFIRMATION COPY

taken e.g. from the introductory chapter "Signals and Channels" in "Telecommunications engineering", ISBN 0-412-38190-7, by J. Dunlop.

For the sake of simplicity and since signal recalculations are mainly applied in the frequency domain, the principle of signal recalculation shall be explained in the following mainly with respect to frequency domain analysis. It is clear, however, that signal recalculations in the time domain applying convolution techniques can be applied accordingly.

Fig. 1 illustrates the principle of signal recalculation in the frequency domain. An input signal 10 provided from a signal source 20 is transmitted through a communication channel generally represented herein as a system 30. In general, the system 30 modifies or distorts the waveform of the input signal 10 transmitted through the system 30 to an output signal 40. The amount of distortion produced by the system 30 is thereby determined by the transfer function (i.e. attenuation and phase shift as a function of frequency) of the system 30. The determination of the transfer function will be explained in more detail with respect to Fig. 2. The output signal 40 is measured by a measuring device 50 such as an oscilloscope.

Before recalculating the input signal 10 from the output signal 40 by a recalculation unit 60, a window function W is usually applied to the measured output signal 40 for reducing spectral leakage effects. Typical window functions are Hanning–Window, Blackman Window, or Hamming Window. The recalculation unit 60 then transforms the windowed signal from the time domain into the frequency domain usually by applying a Fast Fourier Transformation (FFT). The transformed signal is then divided by the transfer function T(f) of the system 30, and the result thereof is retransformed from the frequency domain back into the time domain usually by applying an Inverse Fast Fourier Transformation (IFFT). The result of the retransformation represents a recalculated signal 70, which substantially corresponds to the input signal 10. The recalculated signal 70 might be applied to a signal source 80 for generating a physical signal 90 from the recalculated signal 70 or could be applied for analyzing the recalculated signal 70 with respect to its

characteristics and properties.

It is clear that the recalculated signal 70 ideally equals the input signal 10 in case that:

- the transfer function T(f) applied in the recalculation unit 60 fully equals the transfer function of the system 30,
- the transformation and retransformation steps are completely inverse,
- the measuring device 50 and the recalculation unit 60 have no transfer function(s) further modulating the signals, and
- the window function W has no influence on the signals.

It is clear that any deviation from the ideal situation as outlined above will adversely affect the signal recalculation process and lead to deviations of the recalculated signal 70 from the input signal 10.

Fig. 2 illustrates the principle for determining a transfer function. A reference signal generator 100 applies a reference signal 110 to the system 30 for which the transfer function T(f) is to be determined. The reference signal 110 transmitted through the system 30 is distorted to a signal response 120 measured by a first measuring device 130. The measured signal response 120 is modulated by a window function (block W) and transformed into the frequency domain (block FFT) as a function O(f). Accordingly, the reference signal 110 is measured by a second measuring device 140, modulated by a window function (block W) and transformed into the frequency domain (block FFT) as a function I(f). The transfer function T(f) of the system 30 is then determined in a calculation unit 150 by dividing the frequency-transformed signal response O(f) by the frequency-transformed reference signal I(f).

It is clear that - dependent on the characteristics of the respective signals - the window functions W applied in Figs. 1 and 2 can either be the same or different

window functions.

Another way for determining the transfer function T(f) would be to measure the response of the system 30 to an applied Dirac pulse.

As noted above, the frequency domain analysis executed by the recalculation unit 60 in Fig. 1 can also be undertaken in the time domain, since the time domain and the frequency domain are linked by the Fourier transform. In that case, the recalculation unit 60 would provide a convolution analysis, however, leading correspondingly to the recalculated signal 70.

When performing the recalculation as outlined for Fig. 1, several difficulties have to encountered:

- Firstly, sampling oscilloscopes are generally applied as standard measurement instruments for characterizing (digital) signals, e.g. for determining overshoot or ringing of a digital pulse. For achieving highest accuracy on signal performance measurements, it is necessary to set the time base of the oscilloscope to a value that shows only a few signal periods or even less than one signal period on the screen. This allows maximizing the sampling density of the measured signal. On the other hand, for performing the frequency transformation (such as FFT) a significant number of periods of the measured signal should be used for minimizing the effect of the signal windowing on the measurement accuracy.

  High sampling resolution and to put a huge number of signal periods into one screen shot for minimizing windowing effects, however, are contravening requirements, and a certain trade off between those requirements has to be made. However, it is apparent that any limitation of the sampling accuracy in the measuring process of Fig. 1 will correspondingly lead to a reduced accuracy of the recalculated signal 70 with respect to the input signal 10. Accordingly, any inaccuracy in the sampling process of Fig. 2 (by the measuring devices 130 and 140) will lead to a reduced accuracy of the transfer function T(f), which again

reduces the accuracy of the recalculation process in the recalculation unit 60 of Fig. 1.

- Secondly, the transfer function T(f) can only be determined for discrete frequencies and a limited frequency range. That means, that if the time base of the measuring device 50 has to be changed, the transfer function should be determined again. That requires a huge effort for characterizing each measurement path for all different time bases used.

- Thirdly, even with highest accuracy for the sampling process and determination of the transfer function, the recalculated signal 70 is still slightly distorted under the influence of the windowing function.

- Fourthly, the determination of the transfer function is strongly dependent on the quality of the reference source 100 providing the reference signal 110. Any frequency limitation of the reference source 110 will automatically reduce the accuracy of the determined transfer function.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an improved correction of measured signals. The object is solved by the independent claims. Preferred embodiments are shown by the dependent claims.

According to the invention, the signal correction process can be significantly improved in that - before modulating the corrected measured signal with a window function and recalculating the corrected measured signal - the measured signal is sampled, and the sample sequence is reproduced (preferably copied) to a series of several successive sequences. This signal series of a plurality of the sampled signal sequences is then applied for the windowing process. This allows that the measured signal can be sampled with highest accuracy, while windowing effects can be encountered by choosing a sufficiently high number of the sampled signal sequences put together to the signal series.

Since the invention does not depend on the specific method applied for recalculating corrected measured signals, frequency domain analysis as well as time domain analysis can be applied, as described in the introductory part of the description. Preferably, the recalculation process is performed using a frequency domain transformation of the windowed signal series, and by multiplying the transformed signal series with the inverse transfer function of the system. The result is retransformed into the time domain, and the corrected measured signal can be extracted therefrom preferably by selecting one sequence corresponding to the sequence of the measured signal.

In a preferred embodiment, the corrected signal sequence is selected substantially from a middle range of the signal series resulting from the recalculation process of the windowed signal series.

In another preferred embodiment, a demodulation process inverse to the modulation of the signal series with the window function is applied to the results of the recalculation process of the windowed signal series. This allows further reducing distortion effects resulting from the windowing process.

It is to be understood that the inventive signal sampling and accumulation is not limited to signal recalculations but can be applied in order to reduce windowing effects in any kind of application.

It is clear that the invention can be partly or entirely embodied by one or more suitable software programs, which can be stored on or otherwise provided by any kind of data carrier, and which might be executed in or by any suitable data processing unit.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and many of the attendant advantages of the present invention will be readily appreciated and become better understood by reference to the following detailed description when considering in connection with the accompanied drawings. Features that are substantially or functionally equal or similar will be

referred to with the same reference sign(s).

Fig. 1 illustrates the principle of signal recalculation in the frequency domain,

Fig. 2 illustrates the principle for determining a transfer function, and

Fig. 3 shows a preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 3 shows a preferred embodiment of the invention, whereby the lower part depicts the signal recovery process for correcting a measured signal, and the upper part illustrates the calibration process for determining the transfer function for the signal recovery process. Fig. 3 substantially corresponds to the measuring principles as depicted for Figs. 1 and 2.

The measuring device 50 in Fig. 3, as explained for Fig. 1, measures and samples the output signal 40 of the system 30. However, in contrast with the explanation as given for Fig. 1, the output signal 40 can be sampled with highest accuracy as provided by the measuring device 50. This allows that sampling distortion can be minimized to a high degree. In case of a periodic output signal, e.g. one period can be sampled with maximum sample density for achieving highest accuracy.

The sampled output signal 40 is then applied to a signal multiplication unit 200, which captures the sampled output signal 40 and appends it thereto (n-1)-times. This results in an n-periodic signal, whereby each period represents the sampled output signal 40. In the example of Fig. 3, the sampled output signal 40 is added (or copied) nineteen times to the "original" sampled output signal 40, thus resulting in a 20-periods signal

The n-period signal provided from the multiplication unit 200 is then modulated with a window function W and supplied to the recalculation unit 60. The recalculation unit 60, as explained for Fig. 1, provides a Fourier transform (block FFT) of the windowed n-period signal, divides (block *Xfer) the frequency transformed signal

by the transfer function T(f) of the system 30, and finally retransforms (block IFFT) the result back into the time domain.

The recalculated n-periodic signal provided from the recalculation unit 60 now contains n-times the recalculated signal 70, which again can be received e.g. by selecting one period.

In a preferred embodiment, the recalculated n-period signal provided from the recalculation unit 60 will be demodulated from the windowing function W in a demodulation unit 210. The demodulation unit 210 preferably divides the n-period signal from the recalculation unit 60 by the windowing function W (as applied in the previous windowing process).

In another embodiment, the n-periodic signal from the recalculation unit 60 is applied either directly or via the demodulation unit 210 to a period selection unit 220. The period selection unit 220 selects one period of the n-periodic signal, preferably in a middle range of the n-periodic signal. In the example of Fig. 3, the period selection unit 220 will select the eleventh period of the 20-period signal.

The upper part of Fig. 3 illustrates the calibration process preferably applied for determining the transfer function T(f) of the system 30. It is clear, however, that the transfer function T(f) can also be determined by other processes as known in the art, and that the invention is not limited to the specific embodiment as depicted in the upper part of Fig. 3. In accordance with the above said for Fig. 2, the first measuring device 130 measures and samples the signal response 120 of the system 30, while the second measuring device 140 measures and samples the reference signal 110 applied to the system 30. Also in accordance with the above said, a multiplication unit 200A provides an n-period signal from the sampled signal response 120, and a multiplication unit 200B provides an n-period signal from the sampled reference signal 110. The signal response 120 as well as the reference signal 110 are preferably sampled with highest accuracy achievable by the measuring units 130 and 140. The n-periods signals from the multiplication units 200A and 200B are each modulated with a window function W and transformed into

the frequency domain, as indicated by the respective blocks W and FFT, to a transformed signal response 210A and a transformed reference signal 210B.

The transfer function T(f) can then be determined by dividing the transformed signal response 210A by the transformed reference signal 210B. However, instead of directly dividing the transformed signal response 210A by the transformed reference signal 210B, a cross spectrum and an auto spectrum can be determined, as shown in the upper part of Fig. 3. A cross spectrum unit 225 determines the cross spectrum by complex multiplying the spectra of the transformed signal response 215A and the transformed reference signal 215B. An auto spectrum unit 230 determines the auto spectrum by complex multiplying the spectrum of the transformed reference signal 210B with itself. A transfer function determining unit 240 can then determine the transfer function T(f) by dividing the determined cross spectrum by the determined auto spectrum. This allows eliminating white noise effects thus increasing accuracy.

The determined transfer function T(f) is then preferably stored in a storage 250 and can be requested from the recalculation unit 60.

In a preferred embodiment, an interpolation unit 260 provides an interpolation of the transfer function T(f) from discrete frequency values to a continued frequency spectrum. This is preferably accomplished by a linear interpolation between two discrete frequency points or a spline interpolation.

CLAIMS:

1. A method for correcting a measured signal, preferably a high-speed digital pulse, transmitted through a system, the method comprising the steps of:

(a) sampling the measured signal to a sampled signal sequence,

(b) providing a signal series as a plurality of the sampled signal sequences put together successively,

(c) windowing the signal series with a window function, and

(d) recalculating a corrected measured signal from the windowed signal series using information about the frequency-dependency of the system.

2. The method of claim 1, wherein step (d) comprises the steps of:

(d1) transforming the windowed signal series from time domain into frequency domain,

(d2) modifying the transformed signal series with a transfer function as a function of frequency of the system, preferably by multiplying the transformed signal series with the inverse transfer function of the system,

(d3) re-transforming the modified transformed signal series back from the frequency domain into the time domain, and

(d4) receiving the corrected measured signal from the re-transformed signal series.

3. The method of claim 1 or 2, wherein step (d) further comprises a step of modifying the corrected measured signal with a function inverse to the window function.

4. The method of claim 2 or 3, wherein the step (d4) comprises a step of

selecting a corrected signal sequence substantially corresponding to the sampled signal sequence.

5. The method of claim 4, wherein the selected corrected signal sequence is selected substantially from a middle range of the re-transformed signal series.

6. The method according to any one of the above claims, wherein the sampling in step (a) is executed with high and preferably highest accuracy.

7. A method for correcting a measured signal, preferably a high-speed digital pulse, transmitted through a system having a transfer function as a function of frequency, the method comprising the steps of:

(a) sampling the measured signal to a sampled signal sequence,

(b) providing a signal series as a plurality of the sampled signal sequences put together successively,

(c) windowing the signal series with a window function,

(d) transforming the windowed signal series from time domain into frequency domain,

(e) modifying the transformed signal series with the transfer function of the system, preferably by multiplying the transformed signal series with the inverse transfer function of the system,

(f) re-transforming the modified transformed signal series back from the frequency domain into the time domain, and

(g) receiving a corrected measured signal from the re-transformed signal series.

8. A method for providing a measured signal, preferably a high-speed digital pulse, for further processing, the method comprising the steps of:

(a) sampling the measured signal to a sampled signal sequence, and

(b) providing a signal series as a plurality of the sampled signal sequences put together successively.

9. A software program storable on a data carrier, for executing any one of the above methods when operated in a computer system.

10. An apparatus for executing one of the methods according to any one of the claims 1-9.

11. An apparatus for correcting a measured signal (40), preferably a high-speed digital pulse, transmitted through a system (30), comprising:

means (50)) for sampling the measured signal (40) to a sampled signal sequence,

means (200) for providing a signal series as a plurality of the sampled signal sequences put together successively,

means (W) for windowing the signal series with a window function, and

means (60) for recalculating a corrected measured signal from the windowed signal series using information about the frequency-dependency of the system.

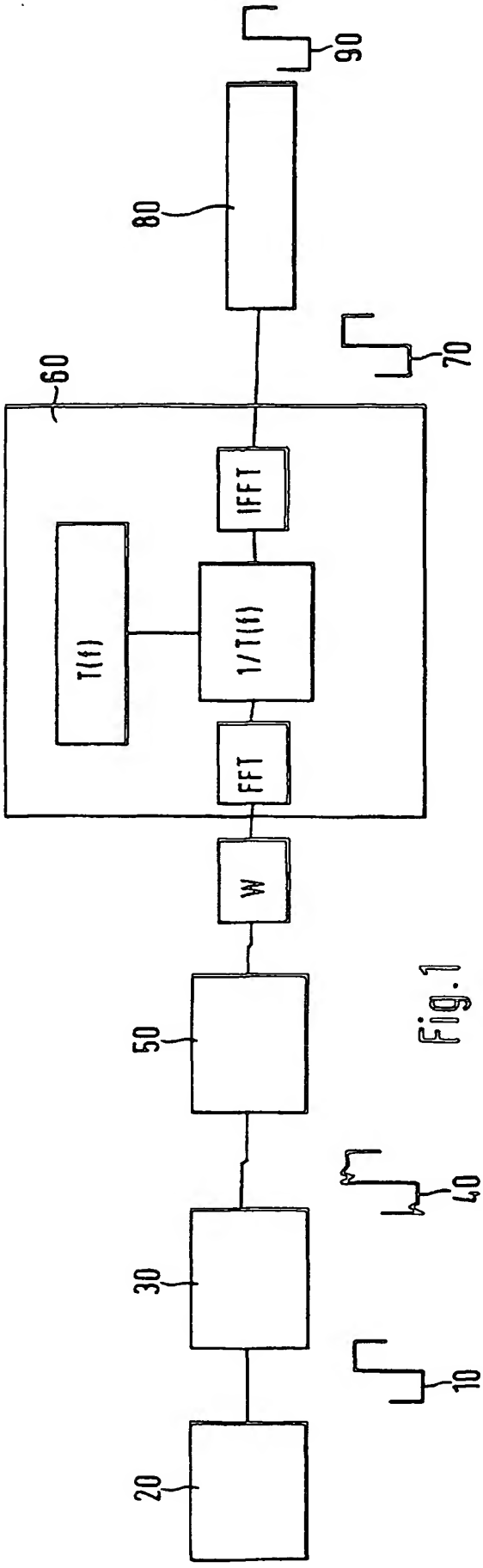

90
80
70
60
IFFT
T(f)
1/T(f)
FFT
W
50
40
30
10
20

Fig. 1

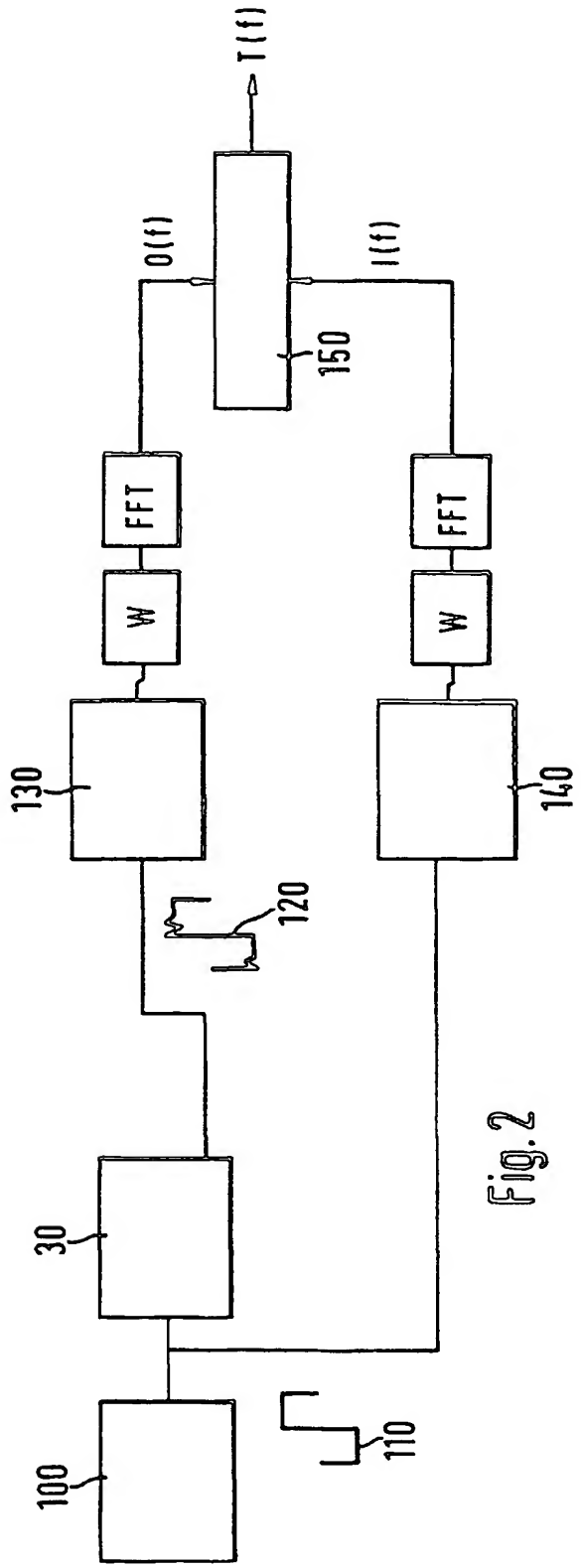

T(f)
O(f)
I(f)
150
FFT
W
FFT
W
130
140
120
30
110
100

Fig. 2

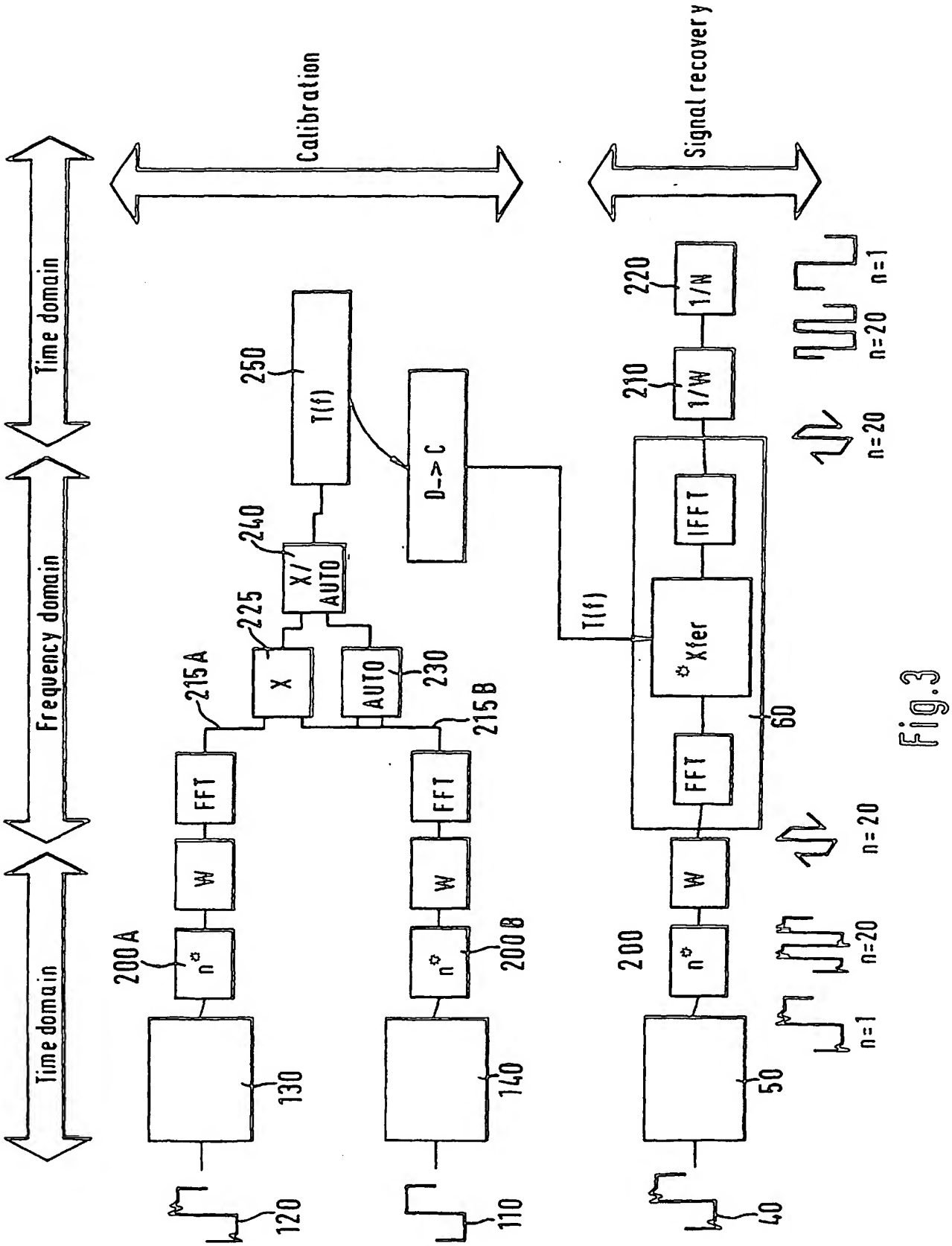

Time domain
Frequency domain
Time domain
Calibration
Signal recovery
120
110
40
130
140
50
200A
200B
200
n*
W
FFT
215A
215B
225
X
AUTO
230
240
X/AUTO
250
T(f)
D->C
T(f)
60
Xfer
IFFT
210
1/W
220
1/N
n=1
n=20
n=20
n=20
n=1

Fig.3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/10349

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R29/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R H03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 702 612 A (FRANCE TELECOM ;TELEDIFFUSION FSE) 16 September 1994 (1994-09-16) abstract; figures 1-4,7,11	1,7-11
A	DE 44 11 098 A (ROHDE & SCHWARZ) 5 October 1995 (1995-10-05) abstract; claim; figure column 1, line 5 - line 38 column 2, line 28 - line 36	1-11
X	US 5 305 242 A (KIKUCHI NORIYOSHI ET AL) 19 April 1994 (1994-04-19) abstract; figures 2A-3B,10 column 1, line 27 - line 47	8-10

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 August 2000	29/08/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Fritz, S

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	LYONS R: "WINDOWING FUNCTIONS IMPROVE FFT RESULTS" TEST AND MEASUREMENT WORLD. (INC. ELECTRONICS TEST),US,CAHNERS PUBLISHING, DENVER, vol. 18, no. 10, 1 September 1998 (1998-09-01), pages 53-54,56,58,60, XP000779830 ISSN: 0744-1657 page 56, last paragraph; figure 3 page 58	1-11
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INTERNATIONAL SEARCH REPORT

information on patent family members

Inte[illegible]al Application No
PCT/EP 99/10349

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